

Isolated power systems for healthcare

When does a healthcare facility require an isolated power system?

BY KEITH LANE, PE, LEED AP, *Partner/Principal, Lane Coburn & Assocs., Seattle*

An isolation power system provides an ungrounded electrical service for various applications within a hospital or a medical office building. These isolation power systems remain in operation in the event of a single line-to-ground fault situation. These systems also eliminate the danger of an electric shock to patients who may be more susceptible to leakage current and unable to move in their bed.

If there is a fault, the system alarm in the isolation panel activates. When the alarm is activated, the critical medical equipment remains operational, because no ground fault protection or overcurrent protective device trips. The triggering of an alarm from a single ground fault must be rectified as soon as possible at a "safe" time, as a second ground fault could trigger the short circuit protection and take an entire operating room offline.

The time current curves for the breakers in Figure 1 represent a 60-amp main breaker and a 20-amp sub-breaker in an operating room. If the panel in the operating room experienced a short circuit current that caused more than 250 amps to flow, the main breaker in the panel could trip—in addition to the 20-amp sub-breaker—and leave the entire operating room without power.

The example does not comply with the requirements of selective coordination required by National Electrical Code (NEC) 517.26, which indicates the following:

• Application of other articles: Essential electrical system shall meet the requirements of Article 700, except as amended by Article 517.

• NEC 700.27: Coordination: Emergency system(s) overcurrent devices shall be selectively coordinated with all supply side overcurrent protective devices.

• NEC 100 Definitions – Coordination (Selective): Localization of an overcurrent condition to restrict outages to the circuit or equipment affected, accomplished by the choice of overcurrent protective devices and their ratings and settings.

If the available fault current at the point of the fault were less than the instantaneous setting of the upstream 60-amp breaker, then the system would be selectively coordinated. In the example shown by the time current curve, the instantaneous of the 60-amp main breaker starts at approximately 250 amps (there is no adjustment in the instantaneous setting; this is a fixed setting). The

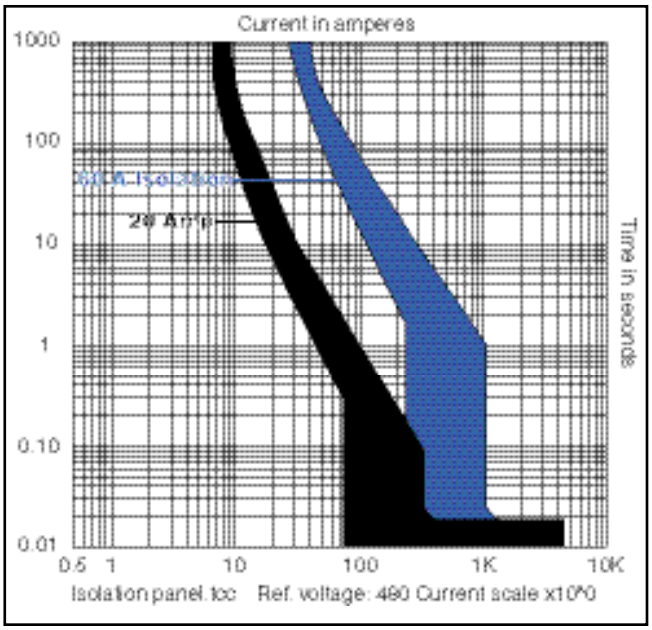


Figure 1 - A short circuit current causing more than 250 amps to flow could leave this entire operating room without power.

60-amp main breaker is associated with a 10-kVA transformer—the largest allowed by NEC Section 517 – 160 (6). The 60-amp breaker is sized based on a maximum of 125% of the output current of the transformer:

10 kVA / 0.208 = 48 amps x 125% = 60 amps

If the transformer has 4% impedance, than the maximum fault current would be approximately 1,200 amps (48 amps / 0.4 = 1,200 amps). This far exceeds the instantaneous setting of the 60-amp main breaker and would therefore not be selectively coordinated according to the definition in the 2005 NEC.

This is an interesting situation; isolated power supply systems that incorporate fuses into the system in lieu of breakers are unusual. Typically, fuses applied in a 2:1 ratio are required to obtain a completely coordinated system. If the system was selectively coordinated, using a 60-amp main fuse and 20-amp sub-fuses, a short

circuit would only take out the single 20-amp breaker and leave the remainder of the operating room in operation. This would still represent a problem—just not as significant of a problem.

The International Electrotechnical Commission (IEC) Regulation 62, "Common Aspects of Electrical Equipment Used in Medical Practice," indicates two critical issues for the use of isolated power systems. These two issues include the requirement for a reliable power supply and the reduction of leakage current.

The definition of isolated power system in the NEC indicates "a system comprising an isolated transformer or its equivalent, a line isolation monitor, and its ungrounded circuit conductors." The NEC also defines a line isolation monitor as a "test instrument designed to continually check the balanced and unbalanced impedance from each line of an isolated circuit to ground and equipped with a built in test circuit to exercise the alarm without adding to the leakage current hazard."

Leakage current can be harmful to people, and hospital patients are even more susceptible to electric shock than healthy individuals

An isolation panel will typically include an isolation panel, a circuit breaker panel, a ground bus, and a line isolation monitor. If the isolation panel becomes unintentionally grounded, the alarm will activate without disconnecting the service. The line isolation monitor is a device that continually measures the balanced and unbalanced impedance from line to ground on each line of an ungrounded electrical distribution system. This measured impedance can be displayed on the unit as hazard current. The amount of hazard current is the amount of current that would flow through a low impendence ground fault on an ungrounded electrical system. If the impedance from line to ground is higher, the amount of hazard current that could flow through the system is lower. The opposite is true if the impedance of the system is lower, the amount of hazard current that could flow through the system would be increased.

Keeping patients safe

Leakage current can be harmful to people, and hospital patients are even more susceptible to electric shock than healthy individuals. A patient in an operating room may not be able to react in a hazardous situation. In addition, the natural impedance of the human skin that can protect against leakage current may be removed from the equation in certain circumstances, such as the insertion of a catheter or other medical procedures. An isolation panel protects the patient from leakage current and potential injury or death.

In a standard transformer, the neutral is bonded to the ground and there is essential no impedance between the neutral and ground. Let's assume for the sake of calculation that a person has approximately 1,000 ohms of impedance. The actual impedance will vary among individuals as well as with the condition and moisture content of the skin. Using the equation below, the amount of fault current through the body could be 120 mA. The equation is as follows:

$$I = V/R = 120 / 1{,}000 = 120 \text{ mA}$$

Where

I = current
V = voltage
R = resistance (impedance)

With the implementation of an isolated power supply, the neutral to ground connection is removed. There will be a very small amount of current flow that is based on the systems leakage capacitance. Even if a person comes in contact with a line conductor and ground and the capacitance between the phase and ground is essentially shunted, the return path through the isolated neutral will greatly reduce the current flowing through the body. This reduction can be 1/1000 or less than the current in a conventional solidly grounded transformer. This could result in 0.1 mA as compared to 120 mA. In addition, a hospital patient may be in a situation that could result in the body having significantly less impedance than what is represented in the equation above. This lower impedance of the body and additional leakage capacitance from multiple pieces of medical equipment connected to the isolated power supply could result in higher levels of current running through the body.

NEC 517.160 (B) (2) states: "The line isolation monitor shall be designed to have sufficient internal impedance such that, when properly connected to the isolation system, the maximum internal current that can flow through the isolation monitor, when any point of the isolation system is grounded, shall be 1 mA."

The perception level of current through the body is about 1 mA. The body would typically feel just a slight tingle at this level of current. At about 5 mA, the body can feel a disturbing pain, but the average person would probably be able to let go and pull away from the shock hazard. But this may not be the case with a sedated or incapacitated hospital patient. Painful shock would occur, and the ability to pull away would occur at between 6 to 25 mA. At 50 to 150 mA, extreme pain and respiratory arrest are possible. Remember, in the example above, 120 mA could flow through the body.

In addition, the shielded isolation panel can prevent power anomalies such as voltage spikes, surges, and noise from damaging the sensitive electronic equipment typically located on operating rooms. This could increase uptime and longevity of the critical medical equipment.

NEC 2005, Section 517-160, Isolated Power Systems, states the following: "Each isolated power circuit shall be controlled by a switch that has a disconnect pole in each isolated circuit conductor to simultaneously disconnect all power. Such isolation shall

be accomplished by means of one or more transformers having no electrical connection between primary and secondary windings, by means of motor generator sets, or by means of suitable isolated batteries."

Additionally, per NEC 517-160 (4), Isolation Transformer, an isolation transformer shall not serve more than one operating room. Note that there are exceptions to this requirement. It is important to maintain the impedance of the electrical system as high as possible. This is achieved by limiting the physical size of the isolation transformer, limiting the number of medical devices connected to the isolation system, and by limiting the total system size. Furthermore, according to NEC 517.160 (A) (6), wire pulling compounds that increase the dielectric constant shall not be used on the conductors on the secondary side of the isolation transformer.

NEC Section 517-160 (6), in the fine-print notes, indicates that the isolation transformer should be limited to 10 kVA or less and that the conductors should use insulation with low leakage to meet the impedance requirements.

Note 2 indicates: "Minimize the length of branch circuit conductors and use conductor insulation with a dielectric constant less than 3.5 and insulation resistance greater than 6100 megohm meters (20,000 megohm ft.) at 16 C reduced leakage from line to ground, reducing hazard currents."

Wet locations

Isolation panels are required for operating rooms that also are considered wet locations (as defined in the NEC) that cannot tolerate a power outage caused by a fault condition. NEC Section 517.20 (A), Receptacle and Fixed Equipment, indicates that "all receptacles and fixed equipment within the area of a wet location shall have ground fault circuit interrupter protection for personnel if interruption of power under fault conditions can be tolerated, or be served by an isolation power system if such interruption cannot be tolerated."

If life-support equipment is part of an operating room, then it is a forgone conclusion that a power outage cannot be tolerated.

Part (B) of this section of the code for isolated power systems indicates that where an isolated power system is used, the isolated power equipment shall be listed as isolated power equipment, and the isolated power system shall be designed and installed in accordance with 517.160.

A ground fault circuit interrupter is described in Section 100 of the 2005 NEC as "a device intended for the protection of personnel that functions to de-energize a circuit or portion thereof within an established period of time when a current to ground exceeds the values established for Class A devices." The fine print note in this section indicates, "Class A ground fault circuit interrupters trip when the current to ground has a value in the range of 4 to 6 mA."

Ground fault

A ground fault through the body typically occurs when some part of a person's body contacts a source of electrical current and the body provides a path for the electrical current to go to the ground, causing a severe shock. An unintentional electric path between a source of current and a grounded surface is referred to as a ground fault. Ground faults occur when current is leaking outside of its intended path; in essence, electricity is escaping to the ground. How it leaks is very significant. If your body provides a path to the ground for this current leakage, you could be burned, injured, severely shocked, or electrocuted.

The ground fault circuit interrupter receptacle constantly monitors electricity flowing in a circuit, to sense any loss of current. If the current flowing through the circuit (hot conductor) differs by a small amount from the current returning (neutral conductor)—4 to 6 mA as indicated above—the ground fault circuit interrupter rapidly switches off power to that circuit. The ground fault circuit interrupter interrupts power very quickly in order to prevent a lethal dose of electricity from flowing through the body. In this situation, the current should remain low enough that you may receive a painful shock, but you should not be electrocuted or receive a serious shock injury. The important point to note is that under a ground fault condition, the ground fault circuit interrupter will disconnect power to the critical piece of medical equipment. If a power interruption cannot be tolerated, this method of protection is not appropriate.

> Class A ground fault circuit interrupters trip when the current to ground has a value in the range of 4 to 6 mA

NEC 517.1, Definitions, defines a wet location as follows: "Wet locations are those patient care areas that are normally subject to wet conditions while patients are present. These include standing fluids on the floor or drenching of the work area, either of which condition is intimate to the patient or staff. Routine housekeeping procedures and incidental spillage of liquids do not define a wet location."

The somewhat vague definition of "wet location" in the NEC gives the engineer and the hospital some flexibility to determine if the electrical distribution system requires the use of an ungrounded power supply. It is important that the engineer and hospital officials discuss the intended procedures that will take place in the operating room before a decision is made whether or not to use isolation power supplies in the electrical distribution system for these critical installations.

Keith Lane is a member of several professional organizations, including BICSI, NFPA, 7x24 Exchange, Illuminating Engineering Society, and the Washington State Society of Healthcare Engineers. He is a member of Consulting-Specifying Engineer's editorial advisory board.